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## SOME EFFECTS OF EXTERNAL STORES ON THE STATIC STABILITY OF FIGHTER AIRPLANES

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# SOME EFFECTS OF EXTERNAL STORES ON THE STATIC STABILITY OF FIGHTER AIRPLANES

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## SUMMARY

Fighter airplanes may have a seemingly limitless number of external store arrangements. Some practical considerations and some aerodynamic considerations must be taken into account in the arrangements of the external stores. This report points out the nature of the problems concerning the type of store arrangement involved and the type of airplane on which the stores are installed as well as some effects of external stores on the static stability of several fighter airplanes. A primary conclusion is that similar types of store arrangements on different types of airplanes may produce different effects on the stability characteristics; this indicates that the effects of stores are more in the "art" stage than in the "science" stage.

## INTRODUCTION

Fighter airplanes of today have a seemingly limitless number of external store arrangements. The types and arrangements of external stores are not the same for all airplanes but differ as to the purpose for which the airplane is used. Many problems arise as a result of the type of store arrangement involved and the type of airplane on which the store is installed. The purpose of this report is to point out the nature of the problems and to present some effects of external store arrangements on the static stability characteristics of a straight-wing, a  $42^{\circ}$  swept-wing, and a  $45^{\circ}$  swept-wing fighter airplane. The material presented is based on results of wind-tunnel tests with models of the three fighter airplanes. These specific airplanes were chosen as representative of airplane configurations with different wing and tail combinations. The stores included armament, fuel tanks, and rocket packets installed on the body and wing tips and pylon-mounted on the wing.

A bibliography of some research on external store arrangements is included.

## SYMBOLS

$C_m$	pitching-moment coefficient
$C_L$	lift coefficient
$C_{n_\beta}$	directional stability parameter
$\alpha$	angle of attack, deg
$M$	Mach number

## RESULTS AND DISCUSSION

### Longitudinal Stability Characteristics

Several store arrangements have been investigated on a straight-wing fighter airplane. These stores included fuel tanks and missiles. Detailed results of the studies may be found in references 1 and 2. A typical wing-tip fuel-tank installation for this fighter is shown on a wind-tunnel model in figure 1. The effects of the wing-tip fuel tanks on the static longitudinal stability characteristics at  $M = 2$  are shown in figure 2. The wing-tip tanks cause a considerable increase in static longitudinal stability when the horizontal tail is off. This increase in stability is due in part to the pitching-moment characteristics of the store itself and in part to an increase in wing lift provided by the end-plate effect of the store. However, for the complete airplane including the horizontal tail, the tip tanks have relatively little effect on the longitudinal stability. This characteristic is an indication of a compensating loss in tail contribution resulting from dynamic-pressure changes or downwash at the tail induced by the presence of the fuel tanks. The straight-wing wind-tunnel model with a large body-mounted store is shown in figure 3. The effects of the store on the pitching-moment characteristics at  $M = 1.8$  are presented in figure 4. A measurable positive increment in pitching moment at zero lift and a slight increase in the longitudinal stability are indicated.

Wind-tunnel studies have been made of a  $45^\circ$  swept-wing fighter with various fuel-tank and missile arrangements (fig. 5). Complete results of these studies are found in reference 3. The stores investigated included large fuel tanks mounted at approximately the midsemispan point under the wing and missiles installed inboard and outboard on the wing. At  $M = 2$ , the large fuel tanks at the wing midsemispan cause no change in the longitudinal stability with the horizontal tail removed, but a measurable reduction in longitudinal stability does occur with the horizontal tail in place. (See fig. 6.) It would

appear from this figure that the decrease in stability is the result of interference of the store on the low horizontal tail.

Several arrangements of fuel tanks and missiles have also been studied on a high-mounted  $42^\circ$  swept-wing airplane. Results of this investigation may be found in reference 4. A unique method of mounting large fuel tanks directly on the sides of the body of this airplane is illustrated in figure 7. Results of the study of the effects of this fuel-tank installation on the longitudinal stability of the  $42^\circ$  swept-wing airplane (ref. 4) indicated that such an arrangement could be used with essentially no effect on the longitudinal stability. Other evidence (unpublished) indicates that fuel tanks may be added to the fuselage of fighter-type airplanes and not only have little effect on the stability characteristics but produce a net reduction in the supersonic wave drag.

The effects of wing-tip-mounted missiles on the straight-wing fighter have also been investigated (refs. 1 and 2). A typical installation for this fighter airplane is shown in figure 8; four missiles are mounted on the wing tips (one over and one under each wing tip). The effects of the wing-tip-mounted missiles on the stability of the straight-wing fighter were similar to the effects of the large fuel tanks mounted on the wing tips, except that the magnitudes of the stability changes were considerably less for the missile installations. The effects of inboard and outboard stores on the  $45^\circ$  swept-wing fighter airplane at  $M = 1.6$  are shown in figure 9. The inboard stores mounted under the wing caused a measurable reduction in static longitudinal stability, whereas the outboard store produced essentially no change in longitudinal stability. This effect can apparently be explained by the fact that the inboard stores were slightly larger than the outboard stores and were located somewhat ahead of the moment reference center. The outboard stores (in addition to being smaller) were located close to the moment reference center of the airplane. Semisubmerged body-mounted missiles on a model of the  $42^\circ$  swept-wing fighter are shown in figure 10; the same missiles in the extended position for firing are shown in figure 11. Results obtained in reference 4 indicated that there was essentially no effect on the longitudinal stability when the missiles were in the semisubmerged position or in the extended position, probably because of the proximity of the missiles to the airplane moment reference center.

#### Lateral-Directional Stability Characteristics

Effects of the wing-tip-mounted missiles on the directional stability of the straight-wing fighter airplane at  $M = 2$  are shown in figure 12. Test results indicated that the tip-mounted missiles produced an increase in the lateral force due to sideslip that varied with the missile installation size. In general, the tip-mounted missiles caused no change in directional stability at low angles of attack but with increasing angle of attack above  $\alpha = 4^\circ$  did cause reductions in directional stability to a measurable degree. The effects

of the large body-mounted store are also shown in figure 12. A significant decrease in directional stability is seen throughout the angle-of-attack range since this store was located slightly forward of the airplane center of gravity. Further results presented in reference 1 indicated that tip-mounted stores generally caused a reduction in the effective dihedral since the effect of the tip stores is to increase the lift-curve slope of the wing and thereby increase the rolling moment provided by the wing in sideslip. The large fuselage store caused an increase in side force below the axes of rotation but still produced an increase in positive effective dihedral. This result indicates the probability that the flow field from the body store causes a loss in lift for the trailing wing panel in sideslip and, thus, an increase in the dihedral effect still occurs.

For the  $45^\circ$  swept-wing fighter airplane at  $M = 1.6$ , the installation of inboard stores resulted in a significant decrease in directional stability throughout the angle-of-attack range (fig. 13). It appears that this adverse effect arises from interference of the store flow field on the vertical tail in addition to the fact that the side force created on the inboard missiles is forward of the airplane center of gravity. The large midsemispan-mounted fuel tanks produced a rather significant increase in directional stability, particularly at angles of attack above about  $10^\circ$  (fig. 13). This effect may be due to the fact that a large part of the increase in side force on the fuel tanks is aft of the airplane center of gravity. Results presented in reference 3 indicated that all the underwing store configurations for the  $45^\circ$  swept-wing fighter, with the exception of the outboard store, caused an increase in positive effective dihedral. This result, again, is apparently caused by a loss in lift on the trailing wing in sideslip due to the store interference flow field.

The effects of the various missile positions on the directional stability of the  $42^\circ$  swept-wing fighter at  $M = 1.6$  are shown in figure 14. The body fuel tanks had little influence on either directional stability or effective dihedral (ref. 4). In figure 14 it is seen that semisubmerged missiles and their subsequent extension progressively decreased the directional stability at the lower angles of attack (below  $\alpha = 12^\circ$ ). Rocket packets attached to the sides of this fighter fuselage are shown in figure 15. It is interesting to note from reference 4 that the rocket packets, which were in the same position as the semisubmerged missiles, had little effect on the directional stability at any angle of attack.

Tests of a delta-wing aft-tail fighter have indicated some interesting characteristics. This configuration, shown schematically in figure 16, consisted of two relatively large winged missiles pylon-mounted under the wing slightly outboard of the tip of the horizontal tail. The test results (unpublished) indicated that the missiles had no effect on the longitudinal stability. Typical effects of the missiles on the directional stability at  $M = 1.6$  are presented in figure 16. A substantial increase in stability was obtained

by the addition of the missiles since, with this planform, it was possible to locate the primary lifting surface of the missile aft of the airplane moment center.

### CONCLUDING REMARKS

In general, results of studies of the effects of external stores on static stability of fighter airplanes indicate that the installation of various missiles or stores on different types of airplanes is still very much an "art" requiring a systematic series of wind-tunnel tests to provide a measure of the influence of the store installation on the stability characteristics. Apparently, at the present time, no reliable technique is available for adequately predicting the effects on stability of the numerous types of store arrangements possible.

Langley Research Center,  
National Aeronautics and Space Administration,  
Hampton, Va., March 29, 1972.

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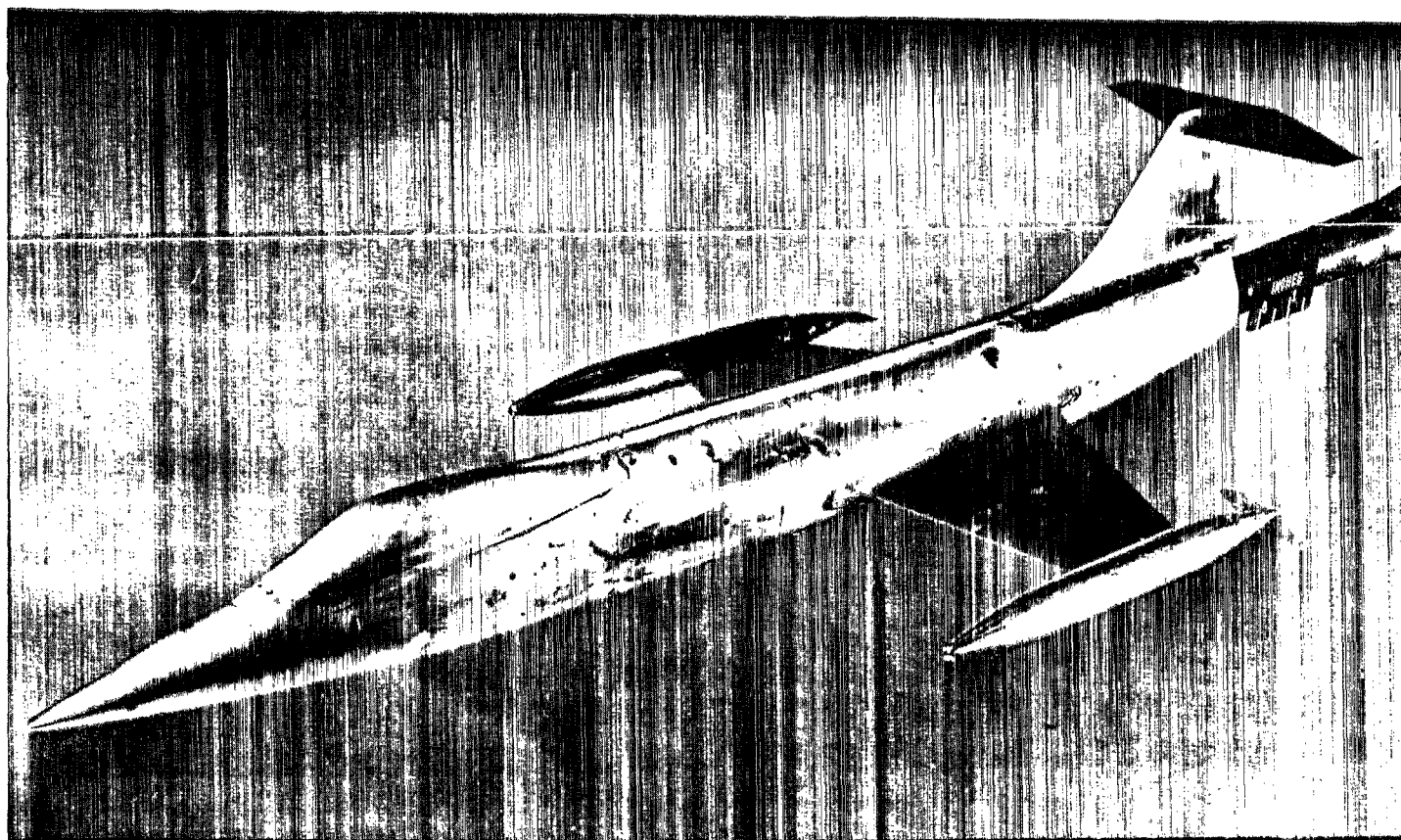
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Figure 1.- Model of straight-wing fighter airplane with wing-tip fuel tanks.

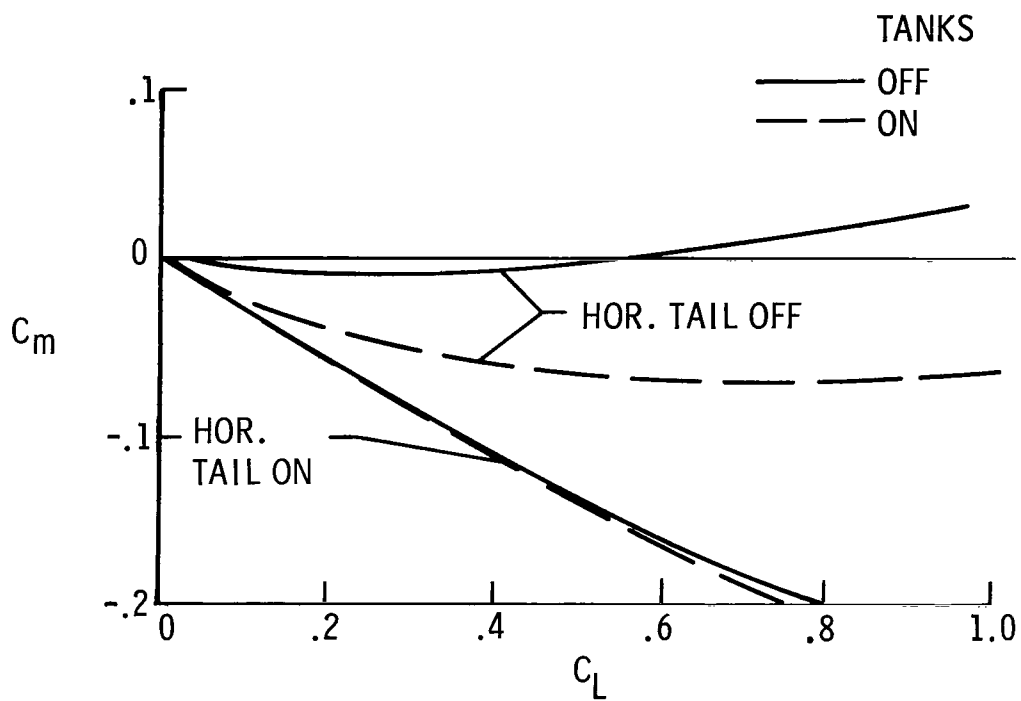
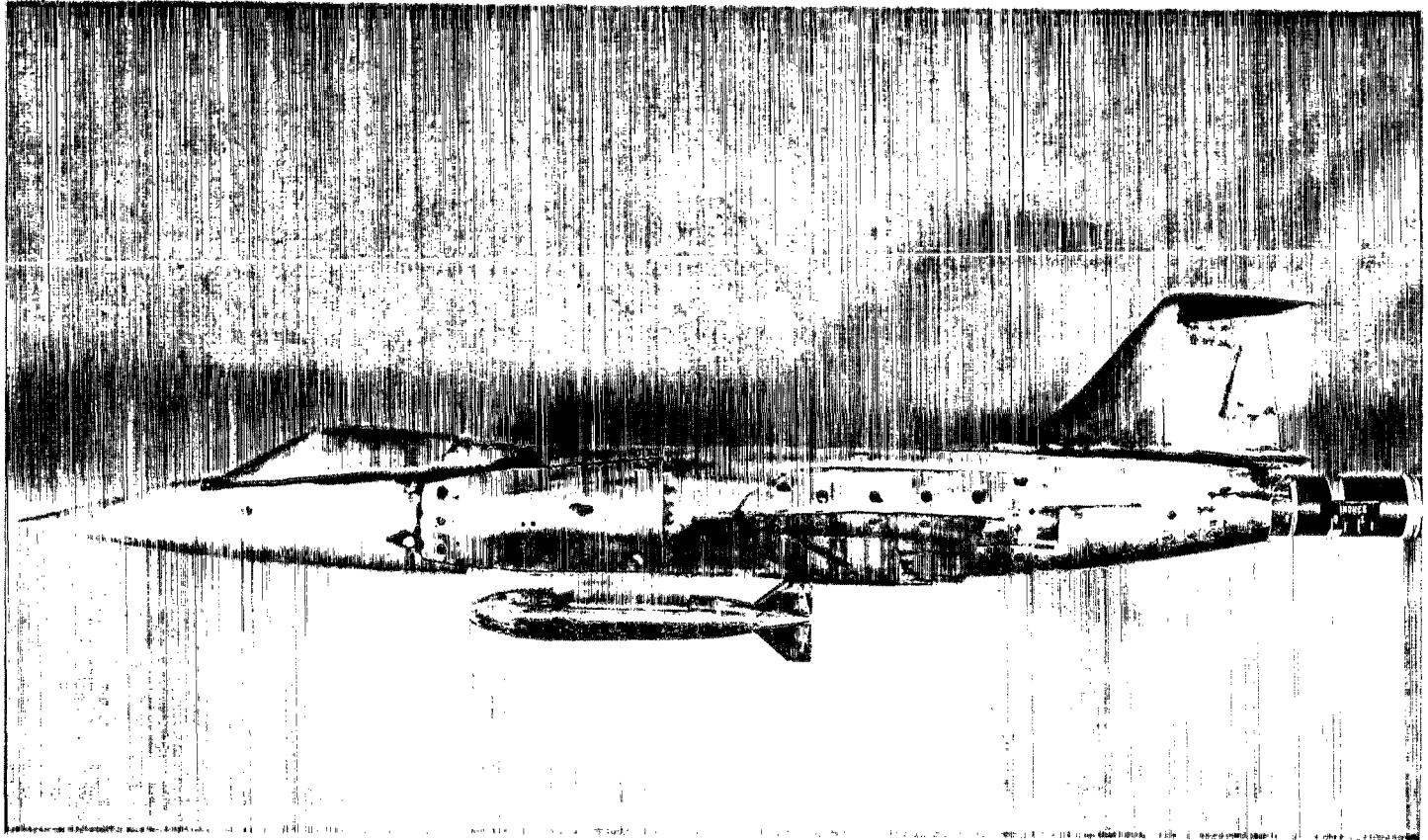


Figure 2.- Effect of wing-tip fuel tanks on longitudinal stability of straight-wing fighter airplane.  $M = 2$ .



L-72-198

Figure 3.- Model of straight-wing fighter airplane with body-mounted store.

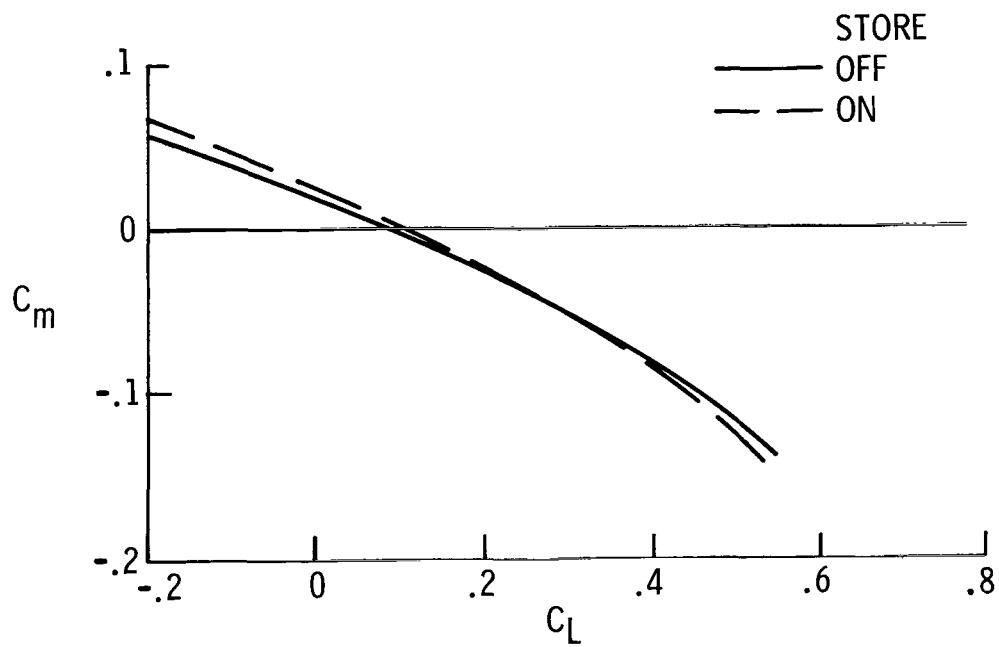


Figure 4.- Effect of body-mounted store on longitudinal stability of straight-wing fighter airplane.  $M = 1.8$ .



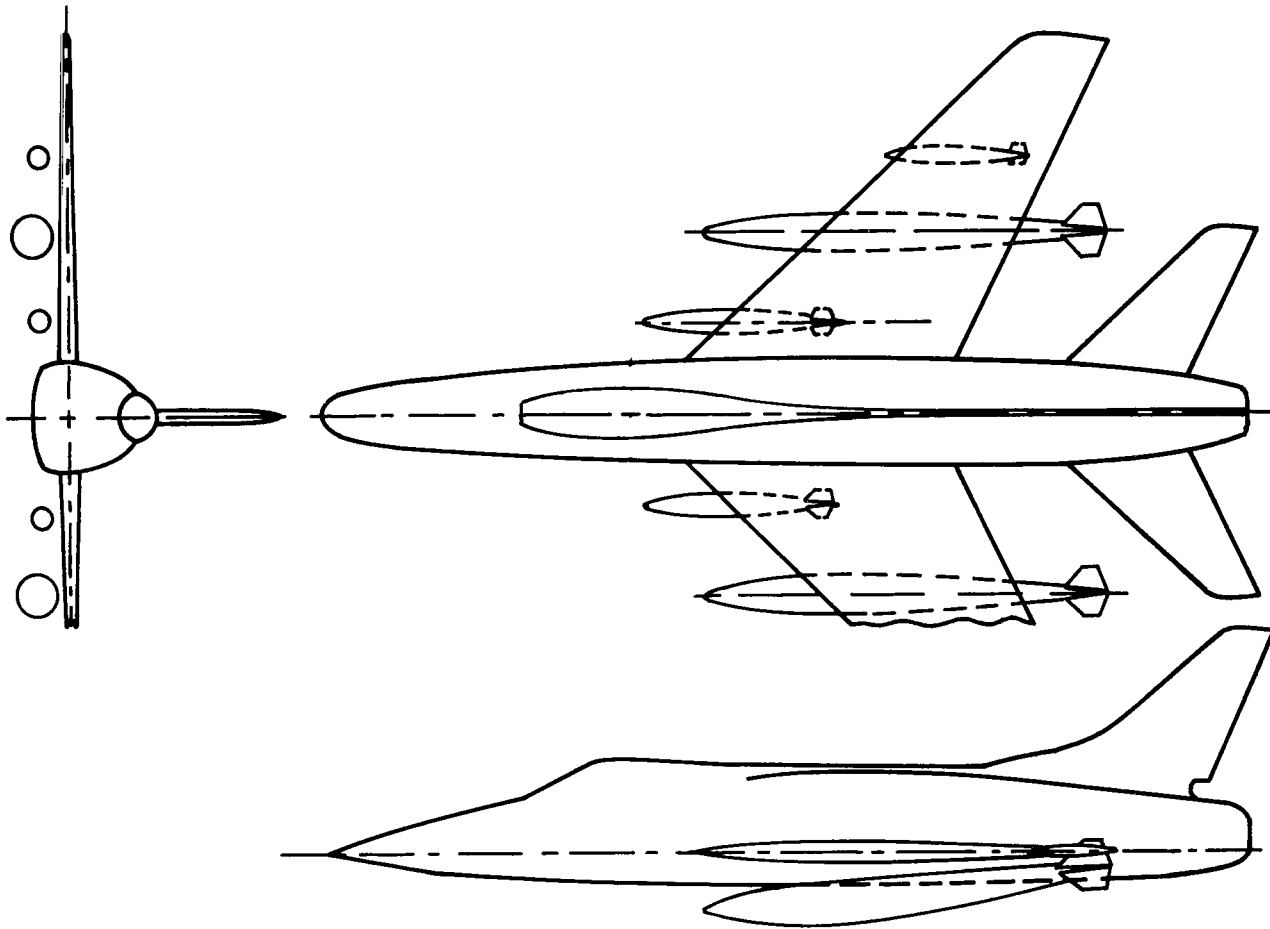


Figure 5.- Location of various stores on model of 45° swept-wing fighter airplane.

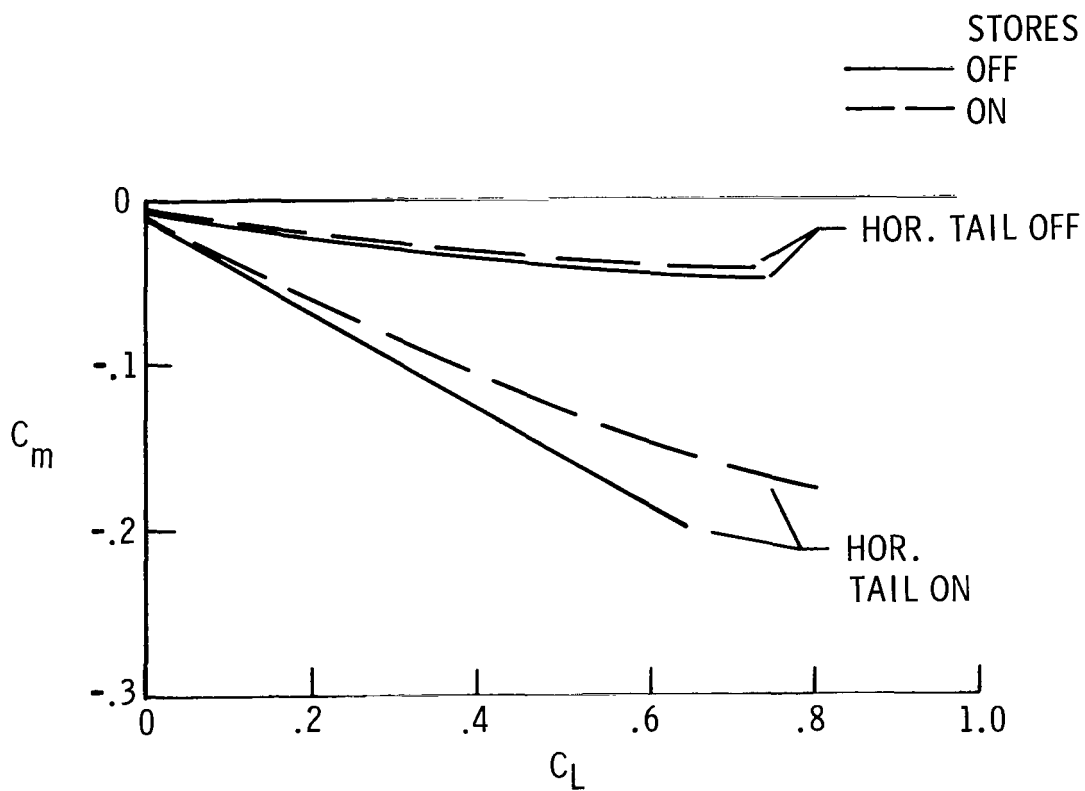
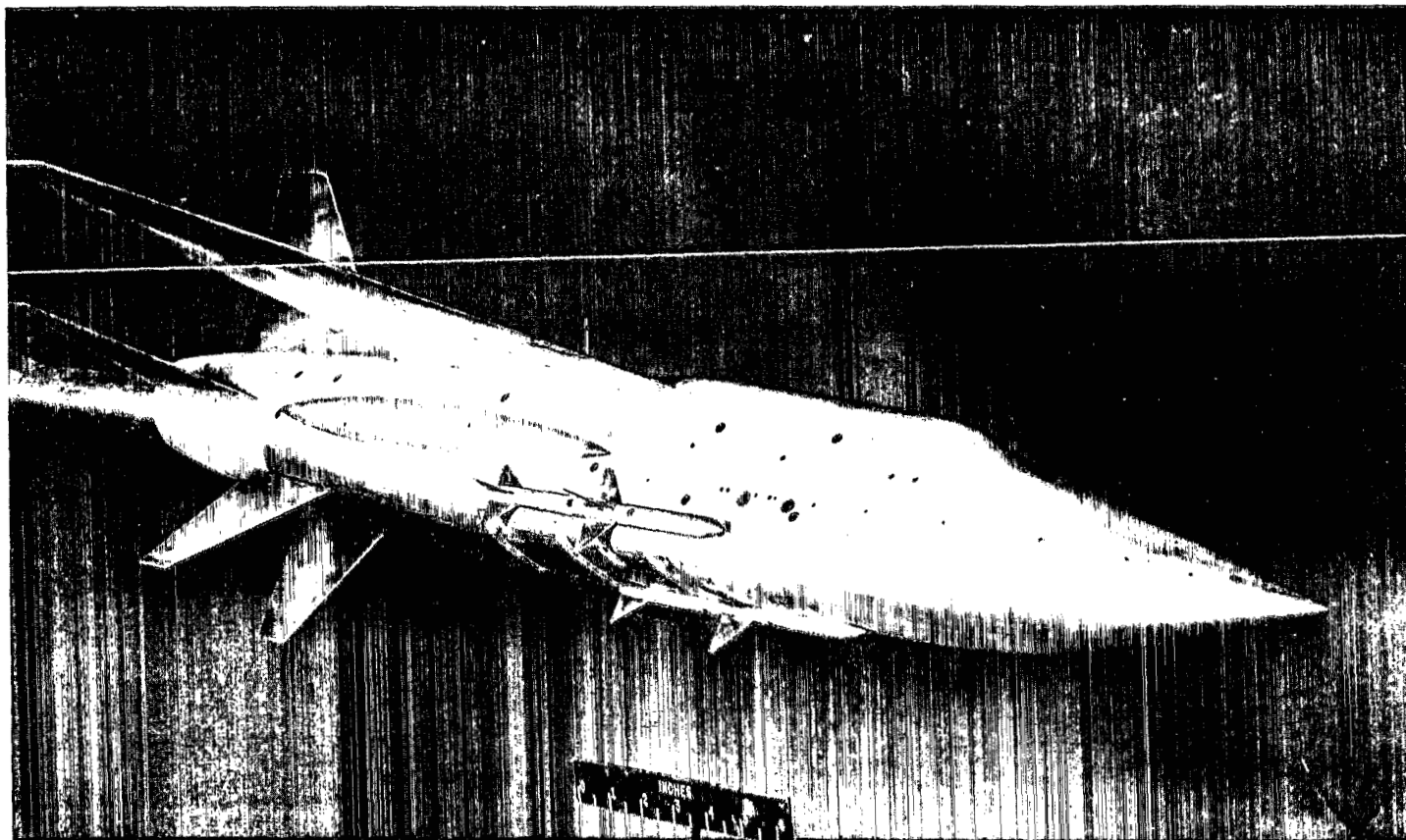
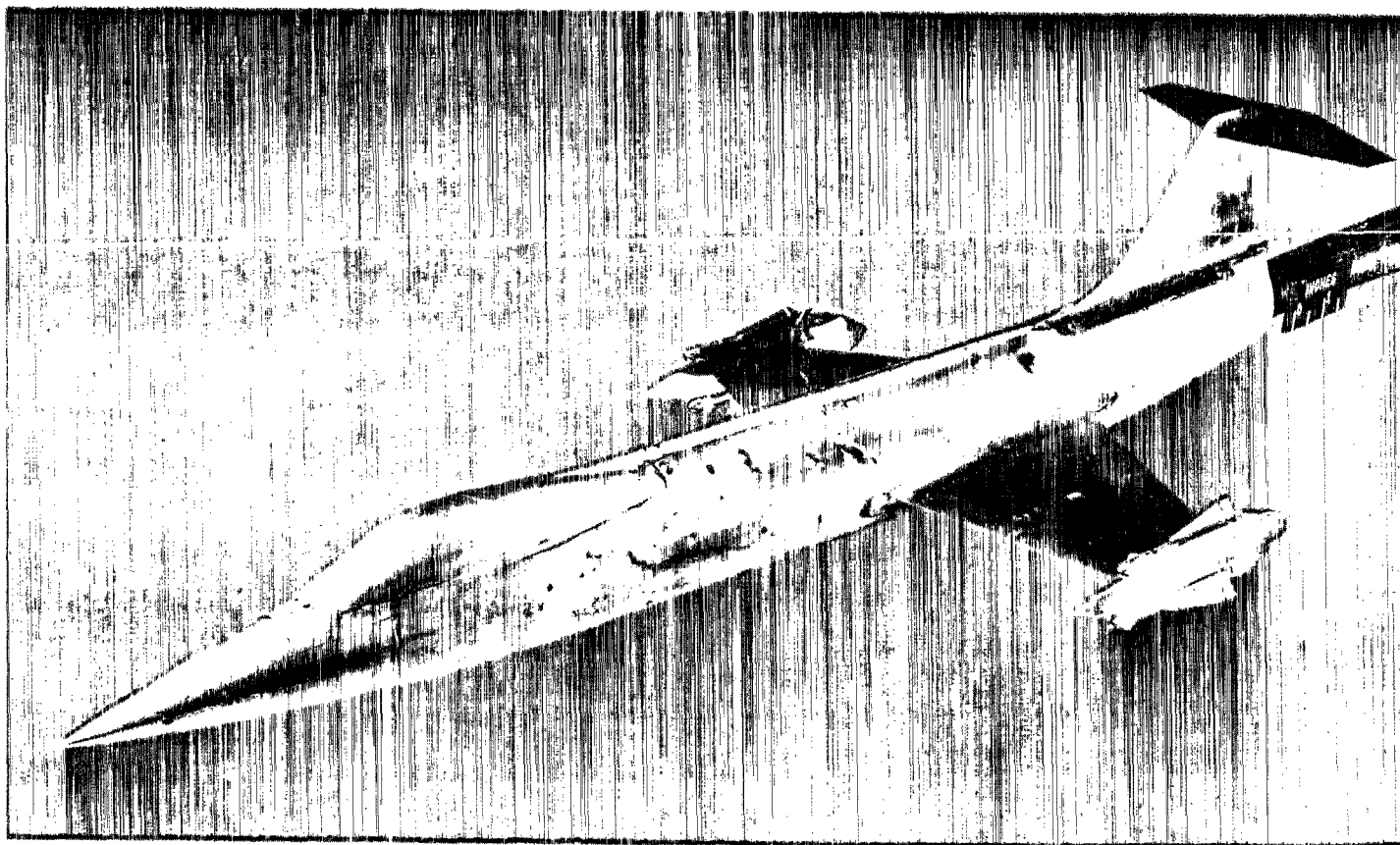


Figure 6.- Effect of large fuel tanks on longitudinal stability of 45° swept-wing fighter airplane.  $M = 2$ .



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Figure 7.- Model of 42° swept-wing fighter airplane with fuel tanks and missiles.



L-72-200

Figure 8.- Model of straight-wing fighter airplane with wing-tip missiles.

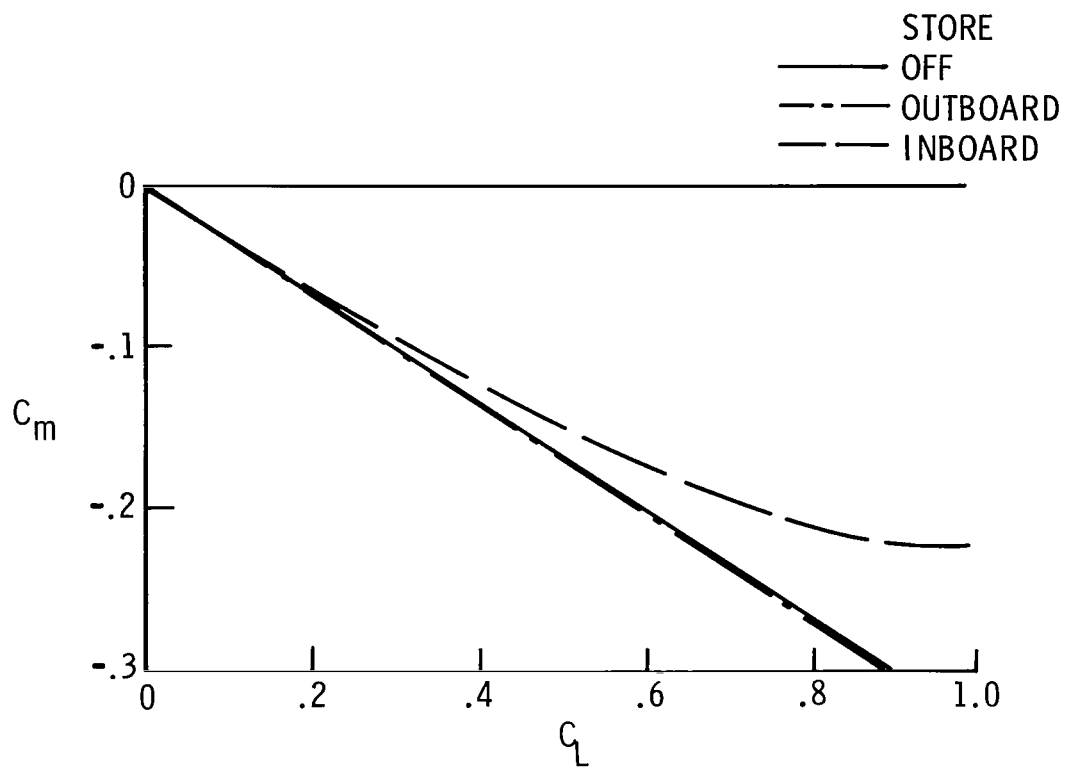
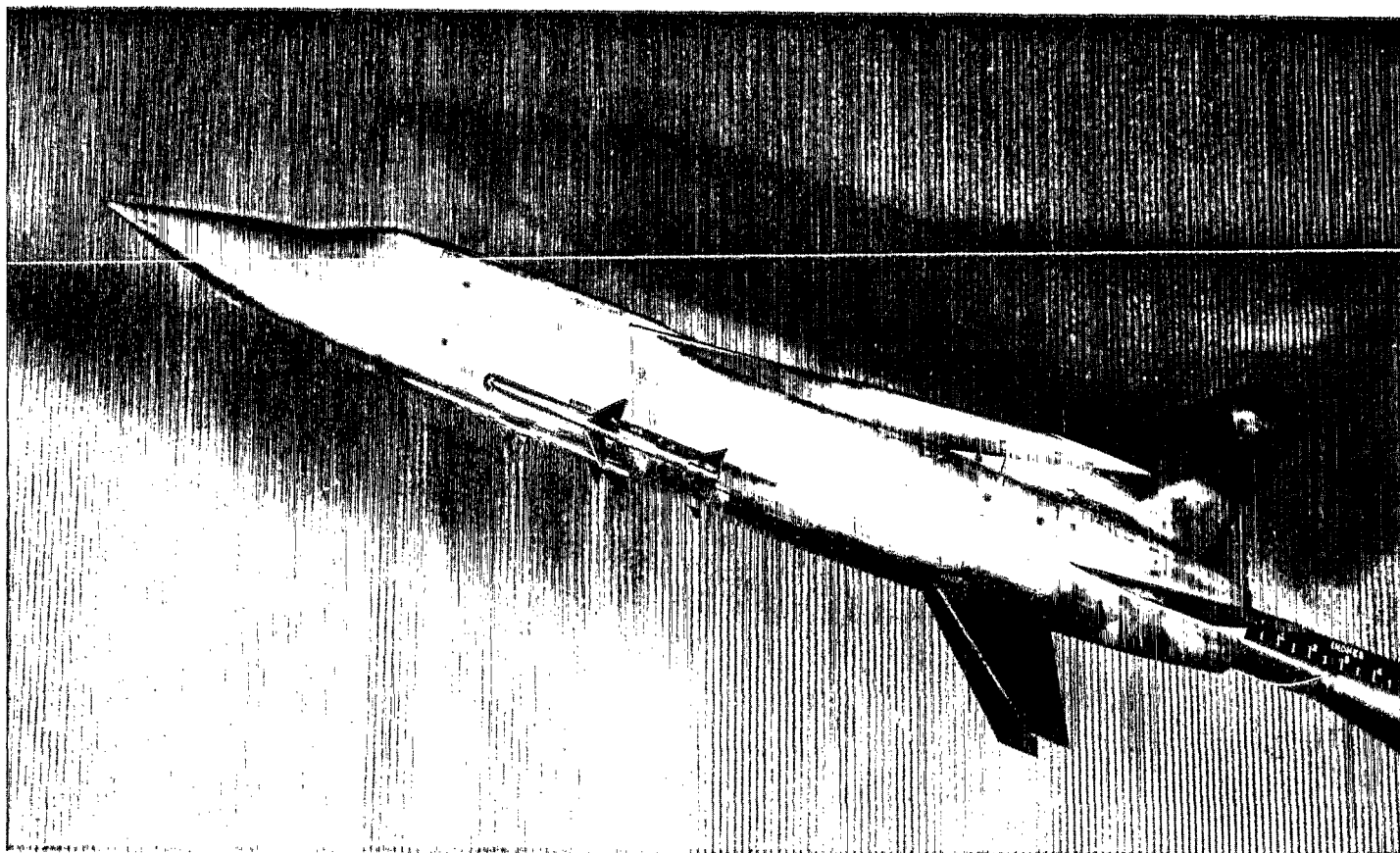
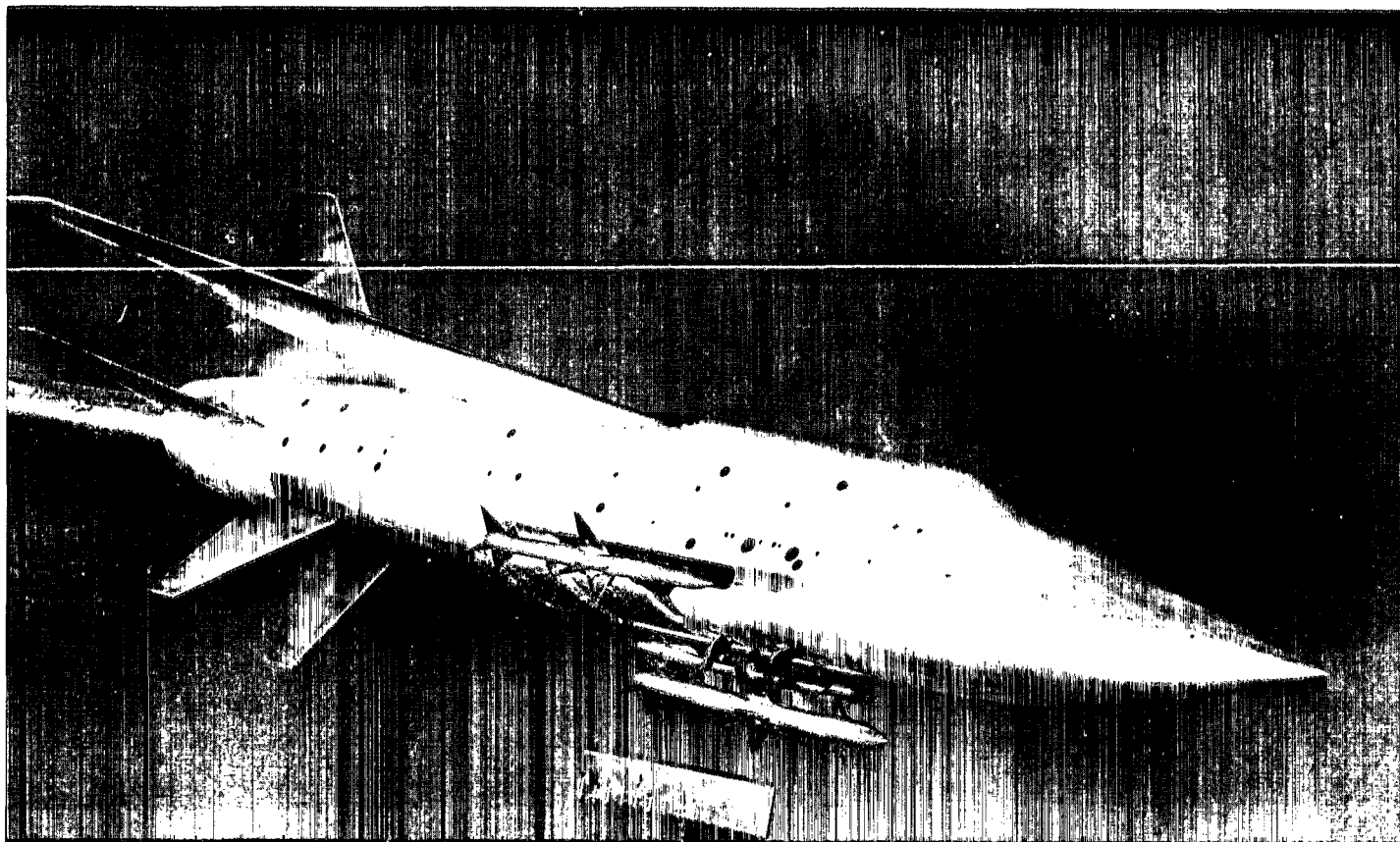


Figure 9.- Effect of inboard and outboard stores on longitudinal stability of 45° swept-wing fighter airplane.  $M = 1.6$ .



L-72-2401

Figure 10.- Model of 42° swept-wing fighter airplane with semisubmerged missiles.



L-72-2402

Figure 11.- Model of 42° swept-wing fighter airplane with missiles extended.

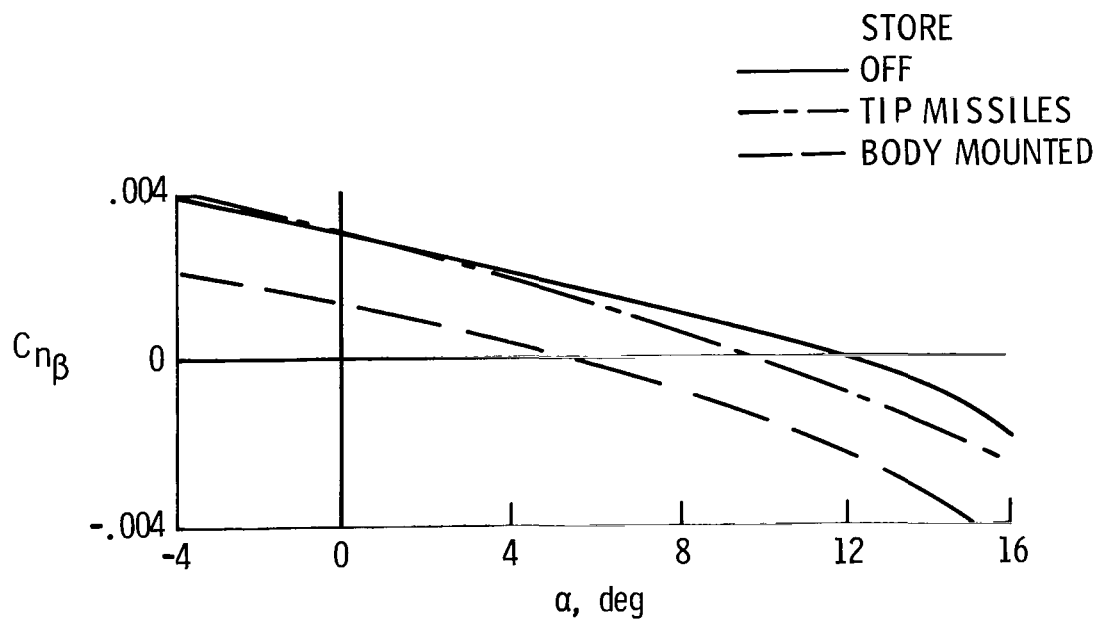


Figure 12.- Effects of stores on directional stability of straight-wing fighter airplane.  $M = 2$ .



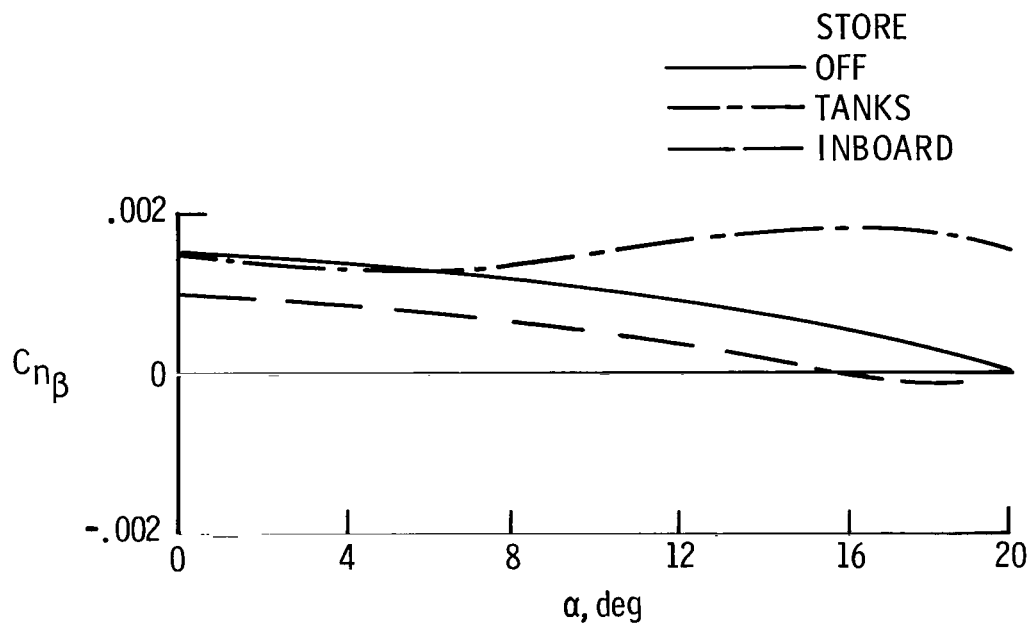


Figure 13.- Effects of stores on directional stability of 45° swept-wing fighter airplane.  $M = 1.6$ .

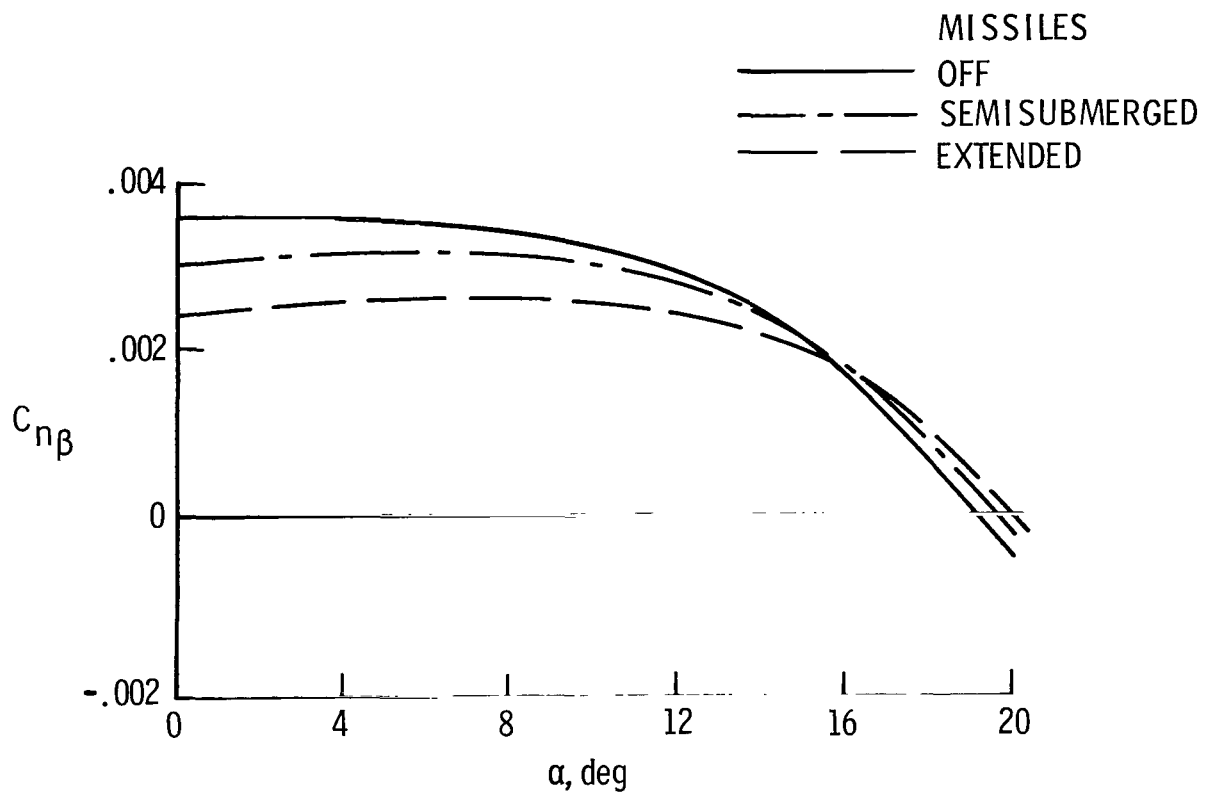
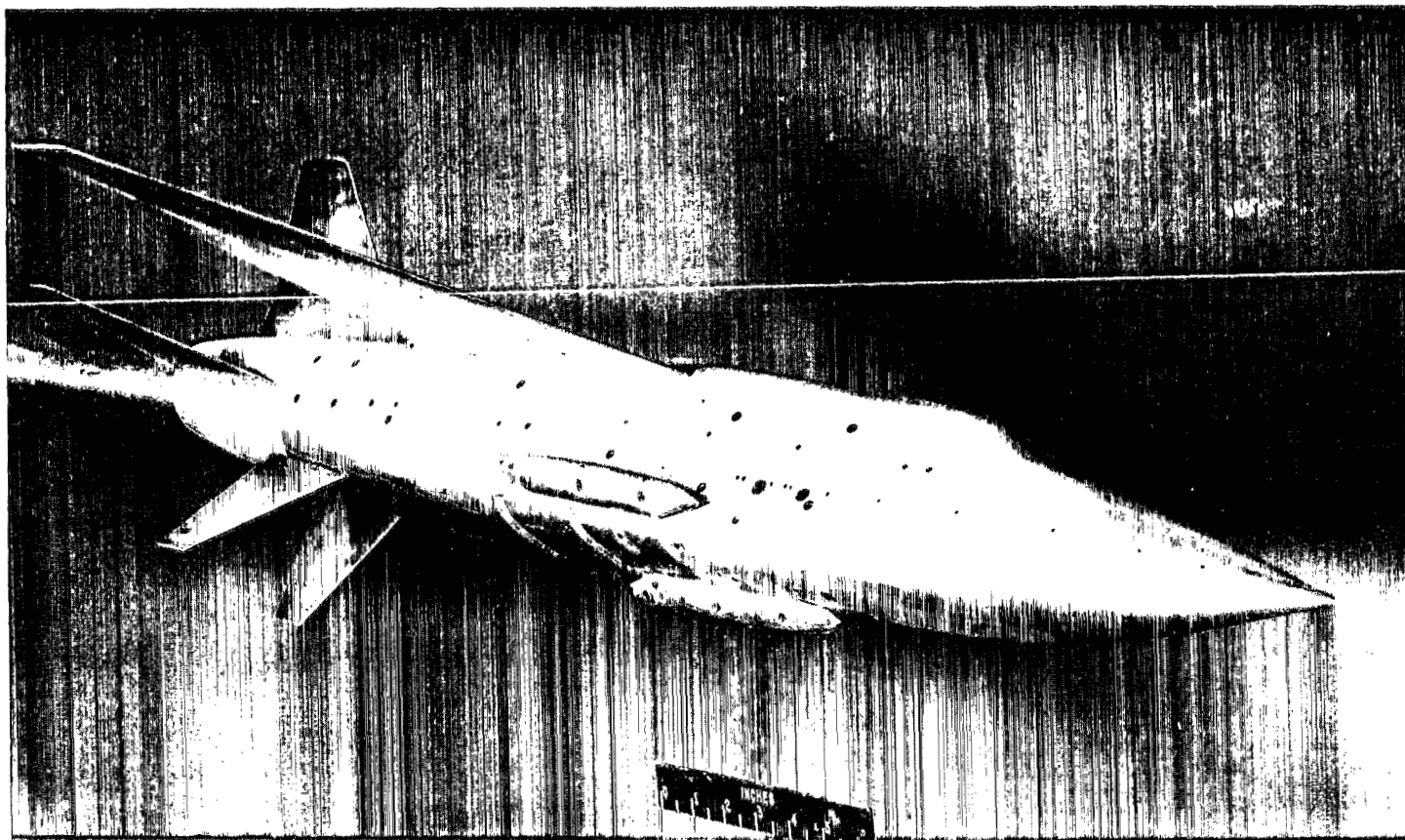


Figure 14.- Effects of missiles on directional stability of 42° swept-wing fighter airplane.  $M = 1.6$ .



L-72-2403

Figure 15.- Model of 42° swept-wing fighter airplane with rocket packets.

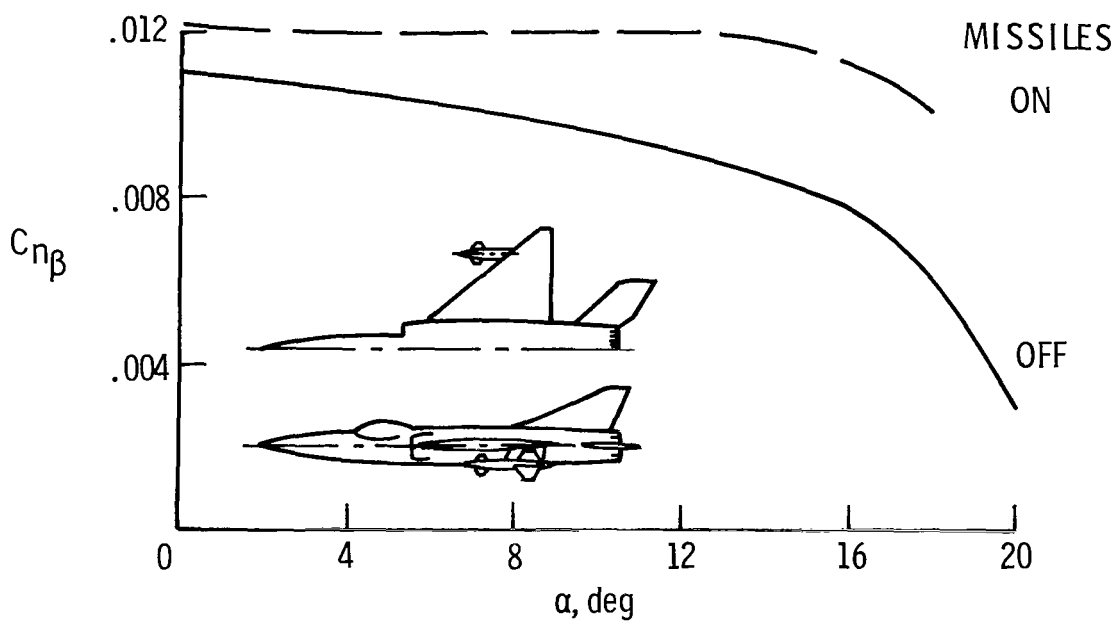


Figure 16.- Effect of missiles on delta-wing fighter airplane.  $M = 1.6$ .



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